The Conservation Status of the World's Reptiles

Monika Böhm[1*], Ben Collen[1], Jonathan E.M. Baillie[2], Philip Bowles[3], Janice Chanson[4,5], Neil Cox[3,4], Geoffrey Hammerson[6], Michael Hoffmann[7], Suzanne R. Livingstone[8], Mala Ram[1], Anders G.J. Rhodin[9], Simon N. Stuart[10,11,12,13,14], Peter Paul van Dijk[12], Bruce E. Young[15], Leticia E. Afuang[16], Aram Aghasyan[17], Andrés García[18], César Aguilar[19], Rastko Ajtic[20], Ferdi Akarsu[21], Laura R.V. Alencar[22], Allen Allison[23], Natalia Ananjeva[24], Steve Anderson[25], Claes Andrén[26], Daniel Ariano-Sánchez[27], Juan Camilo Arredondo[28], Mark Auliya[29], Christopher C. Austin[30], Aziz Avci[31], Patrick J. Baker[32,33], André F. Barreto-Lima[34], César L. Barrio-Amorós[35], Dhruvayothi Basu[36], Michael F. Bates[37], Alexandre Batistella[38], Aaron Bauer[39], Daniel Bennett[40], Wolfgang Böhme[41], Don Broadley[42], Rafe Brown[43], Joseph Burgess[44], Ashok Captain[45], Santiago Carreira[46], Maria del Rosario Castañeda[47], Fernando Castro[48], Alessandro Catenazzi[49], José R. Cedeño-Vázquez[50], David G. Chapple[51,52], Marc Cheylan[53], Diego F. Cisneros-Heredia[54], Dan Cogalniceanu[55], Hal Cogger[56], Claudia Corti[57], Gabriel C. Costa[58], Patrick J. Couper[59], Tony Courtney[60], Jelka Crnobrnja-Isailovic[61], Pierre-André Crochet[53], Brian Crother[62], Felix Cruz[63], Jennifer C. Daltry[64], R. J. Ranjit Daniels[65], Indraneil Das[66], Anslem de Silva[67,68], Arvin C. Diesmos[69], Lutz Dirksen, Tiffany M. Doan[70], C. Kenneth Dodd, Jr.[71], J. Sean Doody[51], Michael E. Dorcas[72], Jose Duarte de Barros Filho[73], Vincent T. Egan[74], El Hassan El Mouden[75], Dirk Embert[76], Robert E. Espinoza[77], Alejandro Fallabrino[78], Xie Feng[79], Zhao-Jun Feng[80], Lee Fitzgerald[81], Oscar Flores-Villela[82], Frederico G. R. França[83], Darrell Frost[84], Hector Gadsden[85], Tony Gamble[86], S.R. Ganesh[87], Miguel A. Garcia[88], Juan E. García-Pérez[89], Joey Gatus[90], Maren Gaulke[91], Philippe Geniez[92], Arthur Georges[93], Justin Gerlach[94], Stephen Goldberg[95], Juan-Carlos T. Gonzalez[16,96], David J. Gower[97], Tandora Grant[98], Eli Greenbaum[99], Cristina Grieco[100], Peng Guo[101], Alison M. Hamilton[102], Kelly Hare[103], S. Blair Hedges[104], Neil Heideman[105], Craig Hilton-Taylor[106], Rod Hitchmough[107], Bradford Hollingsworth[108], Mark Hutchinson[109], Ivan Ineich[110], John Iverson[111], Fabian M. Jaksic[112], Richard Jenkins[113,114,115], Ulrich Joger[116], Reizl Jose[117], Yakup Kaska[118], Uğur Kaya[119], J. Scott Keogh[120], Gunther Köhler[121], Gerald Kuchling[122], Yusuf Kumlutaş[123], Axel Kwet[124], Enrique La Marca[125], William Lamar[126], Amanda Lane[127], Bjorn Lardner[128], Craig Latta[129], Gabrielle Latta[129], Michael Lau[130], Pablo Lavin[131], Dwight Lawson[132], Matthew LeBreton[133], Edgar Lehr[134], Duncan Limpus[135], Nicola Lipczynski[136], Aaron S. Lobo[137], Marco A. López-Luna[138], Luca Luiselli[139], Vimoksalehi Lukoschek[140,141], Mikael Lundberg[142], Petros Lymberakis[143], Robert Macey[144], William E. Magnusson[145], D. Luke Mahler[146], Anita Malhotra[147], Jean

Mariaux[148], Bryan Maritz[149], Otavio A.V. Marques[150], Rafael Márquez[151], Marcio Martins[22], Gavin Masterson[149], José A. Mateo[152], Rosamma Mathew[153], Nixon Mathews[154], Gregory Mayer[155], James R. McCranie[156], G. John Measey[157], Fernando Mendoza-Quijano[158], Michele Menegon[159], Sébastien Métrailler[160], David A. Milton[161], Chad Montgomery[162], Sérgio A. A. Morato[163], Tami Mott[164], Antonio Muñoz-Alonso[165], John Murphy[166], Truong Q. Nguyen[41,167], Göran Nilson[168], Cristiano Nogueira[169], Herman Núñez[170], Nikolai Orlov[24], Hidetoshi Ota[171], José Ottenwalder[172], Theodore Papenfuss[173], Stesha Pasachnik[174], Paulo Passos[175], Olivier S.G. Pauwels[176], Néstor Pérez-Buitrago[177], Valentín Pérez-Mellado[178], Eric R. Pianka[179], Juan Pleguezuelos[180], Caroline Pollock[106], Paulino Ponce-Campos[181], Robert Powell[182], Fabio Pupin[159], Gustavo E. Quintero Díaz[183], Raju Radder[184], Jan Ramer[185], Arne Redsted Rasmussen[186], Chris Raxworthy[84], Robert Reynolds[187], Nadia Richman[1], Edmund Leo Rico[188], Elisa Riservato[189], Gilson Rivas[190], Pedro L. B. da Rocha[191], Mark-Oliver Rödel[192], Lourdes Rodríguez Schettino[193], Willem M. Roosenburg[194], James P. Ross[71,195], Riyad Sadek[196], Kate Sanders[197], Georgina Santos-Barrera[198], Hermann H. Schleich[199], Benedikt R. Schmidt[200,201], Andreas Schmitz[202], Mozafar Sharifi[203], Glenn Shea[127], Hai-Tao Shi[204], Richard Shine[184], Roberto Sindaco[100], Tahar Slimani[75], Ruchira Somaweera[184], Steve Spawls, Peter Stafford[97], Rob Stuebing, Sam Sweet[205], Emerson Sy[206], Helen J. Temple[207], Marcelo F. Tognelli[3,208], Krystal Tolley[209], Peter J. Tolson[210], Boris Tuniyev[211], Sako Tuniyev[211], Nazan Üzüm[31], Gerard van Buurt, Monique Van Sluys[212], Alvaro Velasco[195], Miguel Vences[213], Milan Veselý[214], Sabine Vinke[215], Thomas Vinke[215], Gernot Vogel[216], Milan Vogrin[217], Richard C. Vogt[145], Oliver R. Wearn[1], Yehudah L. Werner[218], Martin J. Whiting[219], Thomas Wiewandt[220], John Wilkinson[221], Byron Wilson[222], Sally Wren[2], Tara Zamin[223], Kaiya Zhou[224], George Zug[102]

***Corresponding author: monika.bohm@ioz.ac.uk**

Running title: Conservation Status of the World's Reptiles

Affiliations

1 Institute of Zoology, Zoological Society of London, Regent's Park, London, NW1 4RY, UK

2 Conservation Programmes, Zoological Society of London, Regent's Park, London, NW1 4RY, UK

3 IUCN - CI Biodiversity Assessment Unit, Conservation International, 2011 Crystal

Drive Ste 500, Arlington, VA, 22202, USA
4 Species Programme, IUCN, Rue Mauverney 28, 1196 Gland, Switzerland
5 IUCN - CI Biodiversity Assessment Unit, c/o 130 Weatherall Road, Cheltenham 3192, Victoria, Australia
6 NatureServe, 746 Middlepoint Road, Port Townsend, WA, 98368, USA
7 IUCN SSC Species Survival Commission, c/o United Nations Environment Programme World Conservation Monitoring Centre, 219 Huntingdon Road, Cambridge, CB3 0DL, UK
8 Ecology and Evolutionary Biology, Faculty of Biomedical & Life Sciences, Graham Kerr Building, University of Glasgow, Glasgow, Scotland, G12 8QQ, UK
9 Chelonian Research Foundation, 168 Goodrich St., Lunenburg, MA, 01462, USA
10 IUCN Species Survival Commission, Rue Mauverney 28, 1196 Gland, Switzerland
11 United Nations Environment Programme World Conservation Monitoring Centre, 219 Huntington Road, Cambridge CB3 0DL, UK
12 Conservation International, 2011 Crystal Drive Ste 500, Arlington, VA, 22202, USA
13 Department of Biology and Biochemistry, University of Bath, Bath BA2 7AY, UK
14 Al Ain Wildlife Park and Resort, PO Box 45553, Abu Dhabi, United Arab Emirates
15 NatureServe, 4600 N. Fairfax Dr., 7th Floor, Arlington, VA, 22203, USA
16 Institute of Biological Sciences, University of the Philippines, Los Banos, 4031 College, Laguna, Philippines
17 Protected Areas Management Department, Bioresources Management Agency of Ministry of Nature Protection, Yerevan, Armenia
18 Estación de Biología Chamela, Instituto de Biología, U.N.A.M., Apdo. Postal 21, San Patricio, Jalisco, 48980, México
19 Departamento de Herpetología, Museo de Historia Natural, Universidad Nacional Mayor de San Marcos, Peru
20 Institute for Nature Conservation of Serbia, dr Ivana Ribara 91, 11070 Belgrade, Serbia
21 Doğa Derneği (Nature Association), Hürriyet cad. 43/12 Dikmen, Ankara, Turkey
22 Departamento de Ecologia, Instituto de Biociencias, Universidade de Sao Paulo, 05508-090 Sao Paulo SP, Brazil
23 Bishop Museum, 1525 Bernice Street, Honolulu, HI 96817, USA
24 Zoological Institute, Russian Academy of Sciences, St.Petersburg 199034 Universitetskaya nab. 1, Russia
25 University of the Pacific, 3601 Pacific Avenue, Stockton, California 95211, USA

26 Nordens Ark, Åby säteri, SE-456 93 Hunnebostrand, Sweden
27 Organización Zootropic, General Projects, 12 Calle 1–25, Zona 10, Edificio Geminis 10, Guatemala 1001, Guatemala
28 Museu de Zoologia, Universidade de São Paulo, Caixa Postal 42494, São Paulo, São Paulo, 04218-170, Brazil
29 Helmholtz Centre for Environmental Research - UFZ, Department of Conservation Biology, Permoserstrasse 15, 04318 Leipzig, Germany
30 Department of Biological Sciences, Museum of Natural Science, Louisiana State University, 119 Foster Hall, Baton Rouge, LA 70803-3216, USA
31 Adnan Menderes University, Faculty of Science and Arts, Department of Biology, Aydın, Turkey
32 Texas A&M University System, AgriLIFE Research, Blackland Research and Extension Center, 720 E Blackland Rd, Temple, TX 76502, USA
33 The Wetlands Institute, 1075 Stone Harbor Blvd, Stone Harbor, NJ 08247, USA
34 Universidade Federal do Rio Grande do Sul - Instituto de Biociências. Avenida Bento Gonçalves 9500, Agronomia. Porto Alegre-RS, Brazil. 91.540-000
35 Fundación Andígena, PO Box 210, Mérida 5101-A, Mérida, Venezuela
36 The Katerniaghat Foundation, C-421 Sector-B, Mahanagar, Lucknow, 226006, India
37 Department of Herpetology, National Museum, P.O. Box 266, Bloemfontein, 9300, South Africa
38 Department of the Environment - Mato Grosso, Brazil
39 Department of Biology, Villanova University, 800 Lancaster Avenue, Villanova, Pennsylvania 19085, USA
40 Mampam Conservation, Glossop, UK
41 Zoologisches Forschungsmuseum Alexander Koenig (ZFMK), Adenauerallee 160, 53113 Bonn, Germany
42 Department of Herpetology, Natural History Museum of Zimbabwe, P.O. Box 240, Bulawayo, Zimbabwe
43 University of Kansas Natural History Museum and Biodiversity Institute, Department of Ecology and Evolutionary Biology, University of Kansas, Dyche Hall, 1345 Jayhawk Blvd, Lawrence, KS 66045-7593, USA
44 Guana Tolomato Matanzas National Estuarine Research Reserve, Ponte Vedra, FL 32082, USA
45 3/1 Boat Club Road, Pune 411 001, Maharashtra, India

46 Laboratorio de Sistemática de Vertebrados e Historia Natural, Instituto de Ecología y Ciencias Ambientales, Facultad de Ciencias (UDELAR) and Museo Nacional de Historia Natural, Montevideo, Uruguay
47 Museum of Comparative Zoology, Harvard University, 26 Oxford Street, Cambridge, MA 02138, USA
48 Departamento de Biología, Universidad del Valle, Cali, Colombia
49 University of California, Berkeley, CA 94720-3160, USA
50 Instituto Tecnológico de Chetumal, Av. Insurgentes No. 330, C.P. 77013, Col. David Gustavo Gtz., Chetumal, Quintana Roo, Mexico
51 School of Biological Sciences, Monash University, Clayton, Victoria 3800, Australia
52 Allan Wilson Centre for Molecular Ecology & Evolution, School of Biological Sciences, Victoria University of Wellington, PO Box 600, Wellington, New Zealand
53 CNRS-UMR5175, Centre d'Ecologie Fonctionnelle et Evolutive, 1919 route de Mende, 34293 Montpellier cedex 5, France
54 Universidad San Francisco de Quito, Colegio de Ciencias Biológicas y Ambientales, calle Diego de Robles y Vía Interoceánica, campus Cumbayá, edif. Darwin, DW-010A. Casilla Postal 17-12-841, Quito, Ecuador
55 University Ovidius Constanta, Faculty of Natural Sciences, Romania
56 Australian Museum, 6 College Street, Sydney, NSW 2010, Australia
57 Museo di Storia Naturale dell'Università di Firenze, Sezione di Zoologia "La Specola", Italy
58 Universidade Federal do Rio Grande do Norte, Natal-RN, Brazil
59 Biodiversity Program, Queensland Museum, PO Box 3300, South Bank, Brisbane Qld 4101, Australia
60 Queensland Department of Employment, Economic Development and Innovation, Southern Fisheries Centre, PO Box 76, Deception 4508, Queensland, Australia
61 Faculty of Sciences and Mathematics University of Niš & IBISS Beograd, Serbia
62 Department of Biological Sciences, Southeastern Louisiana University, Hammond, Louisiana 70402, USA
63 INIBIOMA (CONICET-UNComa), Quintral 1250, (8400) Bariloche, Rio Negro, Argentina
64 Fauna & Flora International, Jupiter House, Station Road, Cambridge, CB1 2JD, UK
65 Care Earth Trust, No 5, 21st Street, Thillaiganganagar, Chennai 600 061, India
66 Institute of Biodiversity and Environmental Conservation, Universiti Malaysia Sarawak, 94300 Kota Samarahan, Sarawak, Malaysia

67 Rajarata University of Sri Lanka, Mihintale, Sri Lanka
68 Amphibian Specialist Group IUCN SSC Working Group, Sri Lanka
69 Herpetology Department, Philippine National Museum, Padre Burgos St, Manila, Philippines
70 Department of Biology, Central Connecticut State University, New Britain, CT 06050, USA
71 Department of Wildlife Ecology and Conservation, University of Florida, Gainesville, FL 32611, USA
72 Department of Biology, Davidson College, Davidson, NC 28035-7118, USA
73 Laboratório de Zoologia de Vertebrados, Universidade Estadual do Rio de Janeiro (LAZOVERTE - UERJ), Brazil
74 Department of Economic Development, Environment & Tourism, P. Bag X 9484, Polokwane 0700, Limpopo, South Africa
75 Université Cadi Ayyad, Département de Biologie, BP: 2390, Marrakech, Morocco
76 Fundacion Amigos de la Naturaleza, Santa Cruz de la Sierra, Bolivia
77 Department of Biology, California State University, Northridge, Northridge, California 91330-8303, USA
78 Karumbe, D. Murillo 6334, Montevideo, Uruguay
79 Chengdu Institute of Biology, Chinese Academy of Sciences, P.O. Box 416, Chengdu, Sichuan, China
80 Xuzhou Normal University, Jiangsu Province, China
81 Texas A&M University, 210 Nagle Hall, College Station, TX 77843-2258, USA
82 Museo de Zoologia, Fac. De Cienicas, Universidad Nacional Autónoma de México (U.N.A.M.), Mexico
83 Universidade Federal da Paraíba, Rio Tinto, PB, Brazil
84 American Museum of Natural History, Central Park West at 79th St., New York, NY 10024, USA
85 Instituto de Ecología, A. C., Chihuahua 31109, Chihuahua, Mexico
86 University of Minnesota, Minneapolis, MN 55455, USA
87 Chennai Snake Park, Rajbhavan post, Chennai 600 022, Tamil Nadu, India
88 Department of Natural Resources, Puerto Rico
89 Museo de Zoologìa, UNELLEZ-Guanare, Venezuela
90 Biology Deptartment, University of San Carlos, Cebu, Philippines
91 GeoBio Center, Ludwig-Maximilians-Universität München, Richard-Wagner-Str. 10, 80333 München, Germany

92 EPHE-UMR5175, Centre d'Ecologie Fonctionnelle et Evolutive, 1919 route de Mende, 34293 Montpellier cedex 5, France
93 Institute for Applied Ecology, University of Canberra, ACT 2601, Australia
94 Nature Protection Trust of Seychelles, 133 Cherry Hinton Road, Cambridge CB1 7BX, UK
95 Whittier College, Department of Biology, Whittier, CA 90608, USA
96 Edward Grey Institute for Field Ornithology, Department of Zoology, University of Oxford, South Parks Road, Oxford OX1 3PS, United Kingdom
97 Department of Zoology, Natural History Museum, London SW7 5BD, UK
98 San Diego Zoo Institute for Conservation Research, 15600 San Pasqual Valley Road, Escondido, CA, 92027, USA
99 Department of Biological Sciences, University of Texas at El Paso, 500 West University Avenue, El Paso, TX 79968, USA
100 Istituto per le Piante da Legno e l'Ambiente, corso Casale 476, I-10132 Torino, Italy
101 Yibin University, Sichuan, China
102 Division of Amphibian & Reptiles, National Museum of Natural History, Smithsonian Institution, Washington, DC 20013, USA
103 University of Otago, 364 Leith Walk, Dunedin 9016. PO Box 56, Dunedin 9054, New Zealand
104 Department of Biology, Pennsylvania State University, University Park, PA, 16802 USA
105 University of the Free State, P.O. Box 339, Bloemfontein 9300, South Africa
106 Species Programme, IUCN, 219c Huntingdon Road, Cambridge, CB3 0DL, UK
107 Department of Conservation, P O Box 10-420, Wellington 6143, New Zealand
108 Department of Herpetology, San Diego Natural History Museum, P.O. Box 121390, San Diego, California 92112, USA
109 South Australian Museum, North Terrace, Adelaide SA 5000, Australia
110 Muséum National d'Histoire Naturelle, UMR CNRS 7205 (Origine, Structure et Evolution de la Biodiversite), Departement Systematique et Evolution, CP 30, 25 rue Cuvier, F-75005 Paris, France
111 Department of Biology, Earlham College, Richmond, Indiana 47374, USA
112 Center for Advanced Studies in Ecology and Biodiversity (CASEB), Catholic University of Chile, Santiago, Chile
113 Madagasikara Voakajy, B.P. 5181, Antananarivo, Madagascar

114 Durrell Institute of Conservation and Ecology, School of Anthropology and Conservation, University of Kent, Canterbury, CT2 7NR, United Kingdom
115 School of Environment, Natural Resources and Geography, Bangor University, Gwynedd, LL57 2UW, United Kingdom
116 State Natural History Museum (Staatliches Naturhistorisches Museum), Pockelsstr. 10, 38106 Braunschweig, Germany
117 Bohol Island State University, Bohol, Philippines
118 Pamukkale University, Department of Biology, Denizli, Turkey
119 Department of Zoology, Section of Biology, Faculty of Science, Ege University, 35100 Bornova/Izmir, Turkey
120 Research School of Biology, The Australian National University, Canberra, ACT 0200, Australia
121 Senckenberg Forschungsinstitut und Naturmuseum, Senckenberganlage 25, D-60325 Frankfurt, Germany
122 School of Animal Biology, The University of Western Australia, 35 Stirling Highway, Crawley, Perth, Western Australia 6009, Australia
123 Dokuz Eylül University, Faculty of Education, Department of Biology, Buca, İzmir, Turkey
124 Staatliches Museum für Naturkunde Stuttgart, Zoologie, Rosenstein 1, D-70191 Stuttgart, Germany
125 Laboratorio de Biogeografía, Escuela de Geografía, Facultad de Ciencias Forestales y Ambientales, Universidad de Los Andes, Apartado Postal 116, Merida, 5101-A, Venezuela
126 University of Texas at Tyler, 3900 University Blvd., Tyler, Tx 75799, USA
127 Faculty of Veterinary Science, University of Sydney, NSW 2006, Australia
128 Colorado State University, Fort Collins, Colorado, 80523, USA
129 Australian Freshwater Turtle Conservation & Research Association (AFTCRA Inc.), 53 Jubilee Road, Carters Ridge, Queensland, Australia
130 WWF - Hong Kong, Hong Kong SAR
131 Universidad Autonoma de Ciudad Juarez, Chihuahua, Mexico
132 Zoo Atlanta, 800 Cherokee Avenue, SE Atlanta, Georgia 30315, USA
133 Global Viral Forecasting Initiative, Cameroon
134 Illinois Wesleyan University, Bloomington, Illinois 61702-2900, USA
135 Environment and Resource Science Division, Department of Environment and Resource Management, Australia

136 WildScreen, Ground Floor, The Rackhay, Queen Charlotte Street, Bristol BS1 4HJ, UK
137 Department of Zoology, University of Cambridge, CB2 3EJ, UK
138 Universidad Juárez Autónoma de Tabasco, División Académica de Ciencias Biológicas, Villahermosa, Tabasco, México
139 Centre of Environmental Studies Demetra, via Olona 7, 00198 Roma, Italy
140 University of California, Irvine, California 92697, USA
141 ARC Centre of Excellence for Coral Reef Studies, James Cook University, Townsville, QLD, 4811, Australia
142 Staatliche Naturhistorische Sammlungen Dresden, Museum für Tierkunde, Königsbrücker Landstr. 159, D-01109 Dresden, Germany
143 Natural History Museum of Crete, University of Crete, 71409 Irakleio, Greece
144 Department of Biology, Merritt College, 12500 Campus Drive, Oakland, CA 94619, USA
145 Instituto Nacional de Pesquisas da Amazônia, Av. André Araújo, 2936, Aleixo, CEP 69083-000, Manaus, Amazonas, Brazil
146 Center for Population Biology, University of California at Davis, Davis, CA 95616, USA
147 School of Biological Sciences, College of Natural Sciences, Bangor University, Deiniol Road, Bangor LL57 2UW
148 Museum of Natural History, Route de Malagnou 1, 1208 Geneva, Switzerland
149 School of Animal, Plant and Environmental Sciences, University of the Witwatersrand, P.O. Wits 2050, South Africa
150 Laboratório de Ecologia e Evolução, Instituto Butantan, Av. Vital Brazil 1500, São Paulo, SP, 05503-900, Brazil
151 Fonoteca Zoológica, Dept Biodiversidad y Biologia Evolutiva, Museo Nacional de Ciencias Naturales (CSIC), José Gutierrez Abascal 2, 28006 Madrid, Spain
152 BIOGES, University of Las Palmas, 35001 Las Palmas, Canary Islands, Spain
153 Zoological Survey of India, North Eastern Regional Centre, Fruit Garden, Risa Colony, Shillong - 793003, Meghalaya, India
154 Wildlife Trust for India (WTI), Species Recovery Program, India
155 Department of Biological Sciences, University of Wisconsin-Parkside, Kenosha, WI 53141, USA
156 Smithsonian Institution Research Associate

157 School of Environmental Sciences and Development, North-West University, Private Bag X6001, Potchefstroom 2520, South Africa
158 Instituto Tecnológico de Huejutla, Carr. Huejutla-Chalahuiyapa, A.P. 94, Huejutla de Reyes, Hidalgo, 43000, Mexico
159 Museo Tridentino di Scienze Naturali, Via Calepina 14, 38122, Trento, Italy
160 Ch. du Bosquet 6, 1967 Bramois, Switzerland
161 CSIRO Marine and Atmospheric Research, PO Box 120, Cleveland 4163 Queensland, Australia
162 Truman State University, Kirksville, MO 63501, USA
163 Universidade Tuiuti do Paraná, Curitiba, Parana State, Brazil
164 Departamento de Biologia e Zoologia, Instituto de Biociências, Universidade Federal do Mato Grosso, Cuiabá, Brazil
165 El Colegio de la Frontera Sur, Chiapas, México
166 Field Museum of Natural History, 1400 S. Lake Shore Dr, Chicago, IL 60605-2496, USA
167 Institute of Ecology and Biological Resources, 18 Hoang Quoc Viet St., Hanoi, Vietnam
168 Göteborg Natural History Museum, Box 7283, SE-402 35 Göteborg, Sweden
169 Departamento de Zoologia, Universidade de Brasilia, ICC Ala Sul - Campus Darcy Ribeiro, Asa Norte, Brasilia-DF, 70910-900, Brazil
170 Museo Nacional de Historia Natural, Interior de la Quinta Normal, Santiago, Chile
171 Institute of Natural and Environmental Sciences, University of Hyogo, Yayoigaoka 6, Sanda, Hyogo 669-1546, Japan
172 Medio Ambiente, Salud & Seguridad Ocupacional, Aerodom SIGLO XXI, Dominican Republic
173 Museum of Vertebrate Zoology, 3101 Valley Life Sciences Building, University of California, Berkeley, CA 94720-3160, USA
174 University of Tennessee, Knoxville, TN 37996, USA
175 Departamento de Vertebrados, Museu Nacional, Universidade Federal do Rio de Janeiro, São Cristovão, Rio de Janeiro RJ, 20940-040, Brasil
176 Département des Vertébrés Récents, Institut Royal des Sciences naturelles de Belgique, Rue Vautier 29, 1000 Brussels, Belgium
177 Universidad de Puerto Rico, Puerto Rico
178 Facultad de Biología, Universidad de Salamanca, Salamanca, Spain

179 Integrative Biology C0930, The University of Texas at Austin, One University Station, Austin, Texas 78712-0253, USA
180 Dep Animal Biology, Fac Sciences, Granada Univer, E-18071 Granada, Spain
181 Bosque Tropical, A. C., Privada Marlin # 10, Fraccionamiento Roca Azul, Jocotepec 45800, Jalisco, Mexico
182 Department of Biology, Avila University, Kansas City, Missouri 64145, USA
183 Universidad Autónoma de Aguascalientes, C. P. 20131, Aguascalientes, Mexico
184 School of Biological Sciences A08, University of Sydney, NSW 2006, Australia
185 Indianapolis Zoo, Indianapolis, IN 46222, USA
186 School of Conservation, The Royal Danish Academy of Fine Arts, Esplanaden 34, DK-1263 Copenhagen K, Denmark
187 USGS Patuxent Wildlife Research Center, National Museum of Natural History, Washington, DC 20013-7012, USA
188 Fauna & Flora International Philippines, c/o International Institute of Rural Reconstruction Y.C.James Yen Centre Silang, Cavite 4118 Philippines
189 Via Maestra 81, I - 28100 Novara Italy
190 Museo de Biologia, Facultad Experimental de Ciencias, La Universidad del Zulia, apartado postal 526, Maracaibo 4011, Estado Zulia, Venezuela
191 Instituto de Biologia, Universidade Federal da Bahia, 40170-290 Salvador, Bahia, Brazil
192 Museum für Naturkunde at the Humboldt University, Invalidenstr. 43, 10115 Berlin, Germany
193 Institute of Ecology and Systematics, La Habana, Cuba
194 Ohio Center for Ecology and Evolutionary Studies, Department of Biological Sciences, Ohio University, 107 Irvine Hall, Athens, Ohio 45701, USA
195 IUCN SSC Crocodile Specialist Group
196 Biology Department, American University of Beirut, Beirut, Lebanon
197 School of Earth and Environmental Sciences, University of Adelaide, Adelaide 5005, Australia
198 Facultad de Ciencias, Universidad Nacional Autonoma de Mexico (U.N.A.M.), Mexico
199 Instituto y Nucleo Zoologico ARCO, E-04200 Tabernas, Spain
200 Institute of Evolutionary Biology and Environmental Studies, University of Zurich, Winterthurerstrasse 190, 8057 Zürich, Switzerland

201 karch, Passage Maximilien-de-Meuron 6, 2000 Neuchâtel, Switzerland
202 Department of Herpetology & Ichthyology, Muséum d'histoire naturelle, 1 route de Malagnou, 1208 Geneve, Switzerland
203 Department of Biology, Razi University, Kermanshah, Iran
204 College of Life Science, Hainan Normal University, Haikou, 571158, China
205 Ecology and Evolutionary Biology, University of California, Santa Barbara, CA 93106, USA
206 Herpetological Society of the Philippines, Philippines
207 The Biodiversity Consultancy, Cambridge, UK
208 Instituto Argentino de Investigaciones de las Zonas Áridas (IADIZA-CONICET), CC 507, CP 5500 Mendoza, Argentina
209 South African National Biodiversity Institute, Private Bag X7, Claremont 7735, Cape Town, South Africa
210 Toledo Zoo, PO Box 140130, Toledo, OH 43614, USA
211 354000 Sochi, ul. Moskovskaya 21, Russia
212 Depto. Ecologia, IBRAG, Universidade do Estado do Rio de Janeiro, Rua São Francisco Xavier 524, Maracanã, CEP 20550-013, Rio de Janeiro, Brazil
213 Technical University of Braunschweig (Technische Universität Braunschweig), 38092 Braunschweig, Germany
214 Palacký University Olomouc, 771 47 Olomouc, Czech Republic
215 Filadelfia 853, 9300 Fernheim, Paraguay
216 Society for Southeast Asian Herpetology, Im Sand 3, D-69115 Heidelberg, Germany
217 DPPVN, Rače, Slovenia
218 Department of Evolution, Systematics and Ecology, The Hebrew University of Jerusalem, 91904 Jerusalem, Israel
219 Macquarie University, Sydney, NSW 2109, Australia
220 Wild Horizons, Inc, Iucson, Arizona 85703, USA
221 Amphibian and Reptile Conservation, 655A Christchurch Road, Boscombe, Bournemouth, BH1 4AP, Dorset, UK
222 University of the West Indies, Mona, Jamaica
223 Department of Biology, Queens University, Kingston, ON K7L 3N6, Canada
224 College of Life Sciences, Nanjing Normal University, Nanjing, China

Abstract

Effective and targeted conservation action requires detailed information about species, their distribution, systematic and ecology as well as the distribution of threat processes which affect them. Knowledge of reptilian diversity remains surprisingly disparate, and innovative means of gaining rapid insight into the status of reptiles are needed in order to highlight urgent conservation cases and inform environmental policy with appropriate biodiversity information in a timely manner. We present the first ever global analysis of extinction risk in reptiles, based on a random representative sample of 1,500 species (16% of all currently known species). To our knowledge, our results provide the first analysis of the global conservation status and distribution patterns of reptiles and the threats affecting them, highlighting conservation priorities and knowledge gaps which need to be addressed urgently to ensure the continued survival of the world's reptiles. Nearly one in five reptilian species are threatened with extinction, with another one in five species classed as Data Deficient. The proportion of threatened reptile species is highest in freshwater environments, tropical regions and on oceanic islands, while data deficiency was highest in tropical areas, such as Central Africa and Southeast Asia, and among fossorial reptiles. Our results emphasize the need for research attention to be focussed on tropical areas which are experiencing the most dramatic rates of habitat loss, on fossorial reptiles for which there is a chronic lack of data, and on certain taxa such as snakes for which extinction risk may currently be underestimated due to lack of population information. Conservation actions specifically need to mitigate the effects of human-induced habitat loss and harvesting, which are the predominant threats to reptiles.

1. Introduction

Reptiles[1] and their immediate diapsid ancestors have had a long and complex evolutionary history, having first appeared on the planet in the late Palaeozoic Era, more than 250 million years ago (based on molecular phylogeny estimates and early fossil records: e.g., Hedges and Poling, 1999; Reisz et al., 2011; van Tuinen and Hadly, 2004). High rates of cladogenesis in the Triassic and Jurassic periods (Vidal and Hedges, 2009) produced a diverse group of animals adapted to almost every

[1] here considered to include the various taxa that belong to the non-avian and non-mammalian amniotes: Crocodylia, Testudines and Lepidosauria (snakes, lizards, amphisbaenians, tuataras)

temperate, tropical and desert environment, and to terrestrial, freshwater and marine habitats. Reptiles play important roles in natural systems, as predators, prey, grazers, seed dispersers and commensal species; they serve as bioindicators for environmental health, and their often specific microhabitat associations provide the ideal study system to illustrate the biological and evolutionary processes underlying speciation (Raxworthy et al., 2008; Read, 1998). Reptiles generally have narrower distributional ranges than other vertebrates such as birds and mammals (Anderson, 1984; Anderson and Marcus, 1992), making them more susceptible to threat processes; however, it should be noted that there is some marked variation in range size between different clades of reptiles, so that generalisations and comparisons may not hold true universally [e.g., range sizes of snakes are generally larger than those of lizards (Anderson and Marcus, 1992)]. This combination of often small range and narrow niche requirements makes reptiles susceptible to anthropogenic threat processes, and they are therefore a group of conservation concern. Regional assessments in Europe (Cox and Temple, 2009) and southern Africa (South Africa, Lesotho and Swaziland; Bates et al., in prep.) indicate that one-fifth and one-tenth of reptilian species respectively are threatened with extinction. It has also been proposed that reptilian declines are similar in taxonomic breadth, geographic scope and severity to those currently observed in amphibians (Gibbons et al., 2000), although this claim was not quantitatively assessed by the authors. Reptilian declines have been attributed to habitat loss and degradation, as well as unsustainable trade, invasive species, pollution, disease and climate change (Cox and Temple, 2009; Gibbons et al., 2000; Todd et al., 2010)

A total of 9,084 species of reptiles have been described so far (Uetz, 2010), and new molecular evidence continues to unearth numerous cryptic species that had not previously been detected by morphological analyses (e.g., Adalsteinsson et al., 2009; Nagy et al., 2012; Oliver et al., 2009). Yet as a group, reptiles are currently poorly-represented on the IUCN Red List of Threatened Species, with only 35% of described species evaluated, and those that are evaluated were done so in a non-systematic manner (IUCN, 2011a). Although the Global Reptile Assessment (GRA) will in the long run address this bias, the current assessment process relies on regional workshops and the formation of IUCN SSC Specialist Groups for specific reptilian taxa, which introduces geographical as well as taxonomic bias into the analysis. Specifically, the Global Reptile Assessment has carried out comprehensive

assessments for North America, Madagascar and New Caledonia, with complete endemic-only assessments having been carried out in the Philippines, Europe and selected island groups (Seychelles, Comoros and Socotra). As a result, there are still large geographical gaps which are only slowly being addressed, namely in Africa, Latin America, Asia and Australia. This limits our understanding of how threat processes affect reptiles, so that these taxa are often overlooked in conservation decisions, specifically because the geographical, taxonomic and threatened species bias still inherent in the current IUCN Red List for reptiles makes taking conservation decisions impractical.

We present the results of the first assessment of extinction risk in a randomly selected, representative and global sample of 1,500 reptiles, as a shortcut for deriving group patterns on which to base sound global conservation action. We produce the first global species- and threatened species-richness maps for reptiles. The results highlight key regions, taxa and anthropogenic threat processes which need to be urgently targeted to effectively conserve the world's reptiles.

2. Methods

2.1 Sampled approach to Red Listing

Following an approach set out in Baillie et al. (2008), we randomly selected 1,500 species from a list of all described reptilian species (Uetz, 2010), using the sample function in R [sample(x, size); R Development Core Team, 2007]. A sample of 1,500 species is sufficiently large to report on extinction risk and trends, and buffers against falsely detecting improvements in extinction risk (Baillie et al., 2008). Similarly, the representation of spatial patterns derived from a sample of 1,500 species was found to be in broad agreement with spatial patterns derived from comprehensive assessments in both mammals and amphibians (Collen et al., in prep.). Although the taxonomy of the full species list by Uetz (2010) does not necessarily follow the taxonomy used by all herpetologists, it is the only comprehensive reptile species list available for the purpose of this project. Nevertheless, taxonomic changes based on new research have been incorporated into the sampled species list throughout the project (e.g., the split of Colubridae into numerous families, as suggested by Zaher et al., 2009). It should be noted that the rapid rate at which new species are being described may have some bearing on the representativeness of our sample in the future. Overall, however, we believe that this sampled approach allows for analysis of extinction risk as well as the depiction of

broad-scale spatial threat status and processes. A full list of species in the sample, and summaries by habitat system and biogeographical realm, are given in Tables S1 and S2 in the online supplementary material.

Our sample closely reflected the contribution of each group towards total reptilian diversity, with the sample being made up of 58% lizards, 37% snakes, 3% turtles/tortoises, 2% amphisbaenians and <1% crocodiles (tuataras were not represented). Overall, 220 of the 1,500 selected species had been previously assessed by IUCN, and these assessments were still up-to-date (i.e., they had been assessed since 2006); for the remaining 1,280 species, new or updated assessments were produced through consultation with a global network of herpetologists and following the IUCN Red List Categories and Criteria (IUCN, 2001). Through a centralised editorial and reviewing process we ensured that the IUCN Red List Categories and Criteria were consistently applied between species and regions. A total of 124 species were re-assessed from previous assessments, and genuine changes (category changes showing a real increase or decrease in extinction risk) or non-genuine changes (changes in category which are due to new or better information becoming available, incorrect information used previously, taxonomic change affecting the species, or previously incorrect application of the IUCN Red List Criteria, rather than a true improvement or decline in Red List category) were noted.

Extinction risk was assessed using the IUCN Red List Categories and Criteria (IUCN, 2001). The IUCN Red List Categories classify species' extinction risk from Extinct (EX) and Extinct in the Wild (EW), via the threatened categories Critically Endangered (CR), Endangered (EN) and Vulnerable (VU) to Near Threatened (NT) and Least Concern (LC). A species is listed as Data Deficient (DD) if insufficient data are available to make a conservation assessment. The Red List categories are assigned objectively based on a number of criteria that indicate level of extinction risk, e.g., rate of population decline (Criterion A), population size (Criteria C and D), geographic range size and decline (Criterion B), or quantitative analyses (Criterion E) (IUCN, 2001; Mace et al., 2008). Given the nature of biological information available for reptiles, and the general lack of population data for this group, most of the threatened species in the sample were listed on the basis of restricted geographic range under criteria B or D2 (see Appendix S3 in the online supplementary material for more information on the assessment process and the use of criteria).

Threats were recorded for each species. These were coded following Safalsky et al. (2008) and broadly defined as: threats due to agriculture/aquaculture; biological resource use (e.g., hunting and harvesting of species; logging activities); urban

development (residential and commercial); pollution; invasive or problematic species; energy production and mining (oil drilling and mining); natural system modifications (e.g., fire regimes, damming and channelling of waterways); climate change and severe weather; human intrusion and disturbance; transportation and service corridors (e.g., roads and shipping lanes); and geological events.

All of the species assessments have been reviewed and accepted by the IUCN and are now published online (www.iucnredlist.org, IUCN, 2011a), with the exception of some turtle and crocodilian assessments which are still undergoing sign-off.

2.2 Species distributions and maps of threat processes

Distributions were mapped in ArcGIS for 1,497 species [three species lacked adequate distributional data: *Anolis baccatus* (DD), *Dipsas maxillaris* (DD), *Typhlops filiformis* (DD)], based on georeferencing of distribution maps published in the literature, conversion of point locations into ranges and expert feedback. Only extant ranges were included in the analysis (i.e., extinct, possibly extinct and uncertain parts of the range were omitted). We produced maps of global species richness, threatened species richness and Data Deficient species richness, by overlaying a hexagonal grid onto the aggregated species' distribution. The grid is defined on an icosahedron, projected to the sphere using the inverse Icosahedral Snyder Equal Area (ISEA) projection, and takes account of the Earth's spherical nature. We then summed the number of species occurring in each hexagonal grid cell (cell size was approximately 7,770 km^2) to obtain the species richness pattern of our sample. We also mapped the proportion of species classed as threatened (CR, EN and VU categories), Near Threatened and Data Deficient per grid cell.

We mapped underlying threat processes for all 1,497 mapped species as the number of threatened and Near Threatened species within each grid cell affected by the threat process in question. We expressed threat process prevalence using two approaches. Approach A used the number of species affected by a predominant threat and approach B the proportion of species affected by each predominant threat type out of the total number of species (all categories) present in each grid cell. Although coarse in resolution, as threat processes are unlikely to be equally distributed across a species' range, these aggregations provide an impression of those locations where each threat is affecting a particularly large number of species. The two approaches to

threat mapping are likely to emphasise different aspects of the pattern, with approach A more likely to be influenced by underlying species richness patterns, and approach B by threat patterns being observed across areas of low reptile numbers in our sample, where the presence of threat in one or a few species is going to result in a larger proportional value compared to species rich areas. It is also likely to be more easily affected by biases in our sample in areas of overall low reptile numbers. In terms of conservation action, approach A is likely to correspond most closely to prioritisation measures which maximise species richness through targeted conservation (similar to hotspot approaches, although in this case driven by underlying threat processes), while approach b) gives a better indication of areas where a threat process is affecting a larger proportion of species (though most likely in areas of low species richness).

2.3 Summarizing the extinction risk of the world's reptiles

We summarized extinction risk across all reptiles and sub-groups (amphisbaenians, crocodiles, lizards, snakes, turtles/tortoises), and by biogeographical realm (see S3.3 in the online supplementary material for information on the geographical extent of biogeographical realms) and habitat system (terrestrial, freshwater, marine). We calculated proportions of threatened (Critically Endangered, Endangered and Vulnerable) species by assuming that Data Deficient species will fall into these categories in the same proportion as non-Data Deficient species:

$$Prop_{threat} = (CR+EN+VU)/(N\text{-}DD),$$

where N is the total number of species in the sample, CR, EN and VU are the numbers of species in the Critically Endangered, Endangered and Vulnerable categories respectively, and DD is the number of species in the Data Deficient category. Threat levels have been reported in this way in similar studies (e.g., Clausnitzer et al., 2009; Hoffmann et al., 2010; Schipper et al., 2008), representing the current consensus among conservation biologists about how the proportion of threatened species should be presented, while also accounting for the uncertainty introduced by DD species. The approach is likely to result in a conservative estimate of threat proportions, since Data Deficient reptiles are often rare and restricted in range, thus likely to fall within a threatened category in future based on additional data [although in other taxa, indications are that DD species will often fall into Least Concern categories (e.g., birds; Butchart and Bird, 2010) or remain largely Data Deficient (e.g., mammals; Collen et al., 2011)]. Overall, the re-assessment of DD species into different

categories is very taxon-specific and depends greatly on the attitude of the assessor to risk, so that it is difficult to make any generalisations about what the future status of DD species might be. To deal with this uncertainty we calculated upper and lower bounds of threat proportions by assuming that (a) no Data Deficient species were threatened [lower margin: $Prop_{threat}$ = (CR+EN+VU)/(*N*)], and (b) all Data Deficient species were threatened [upper margin; $Prop_{threat}$ = (CR+EN+VU)/(*N*+DD)].

2.4 Taxonomic differences in extinction risk and the effect of range size

We followed Bielby et al. (2006) to evaluate whether extinction risk is randomly distributed across taxonomic families [based on the taxonomy by Uetz (2010), but including some Australasian geckos in the Diplodactylidae (Han et al., 2004), see Table S1 for details], and tested for significant variation in threat levels across families using a chi-square test. The absence of a random distribution of risk suggests that biological or geographical drivers of risk exist, which can help focus conservation activity (Cardillo and Meijaard, 2011). Where we detected taxonomically non-random extinction risk, further analyses were employed to determine which families deviated from the expected level of threat. Using binomial tests, we calculated the smallest family size necessary to detect a significant deviation from the observed proportion of threatened species and excluded families represented by an insufficient number of species from subsequent analysis. We generated a null frequency distribution of the number of threatened species from 10,000 unconstrained randomizations, by randomly assigning Red List categories to all species, based on the frequency of occurrence of each category in the sample. We then counted the number of threatened species in the focal family and compared this with the null frequency distribution. The null hypothesis (extinction risk is taxonomically random) was rejected if this number fell in the 2.5% at either tail.

Because reptiles are mostly listed as threatened under the range-size dependent criteria B and D2, we explored differences in range size between species groups (specifically between lizards and snakes) in order to assess whether increased threat status in the absence of population data could be potentially linked to taxa-specific patterns of range size. This is particularly of interest since it has previously been observed that snakes have larger range sizes (and hence extent of occurrences) than lizards (Anderson, 1984; Anderson and Marcus, 1992). All tests and randomizations were conducted in R version 2.11.1 (R Development Core Team, 2007).

3. Results

3.1 Global extinction risk of reptiles

We classified more than half of reptilian species (59%) in the assessment as Least Concern (LC), 5% as Near Threatened, 15% as threatened (Vulnerable, Endangered or Critically Endangered) and 21% as Data Deficient. Based on this, we estimated the true percentage of threatened reptiles in the world to be 19% (range: 15–36%), as described in section 2.3. Using the same approach, another 7% of species are estimated as Near Threatened (range: 5–26%); these species are the most likely candidates to become threatened in the future if measures are not taken to eliminate anthropogenic processes which currently affect populations of these species. None of the species in our sample was classed as Extinct or Extinct in the Wild, although three lizard species in the Critically Endangered category were flagged as possibly extinct (*Anolis roosevelti*, *Ameiva vittata* and *Stenocercus haenschi*) and may be up-listed during future reassessments, once "exhaustive surveys in known and/or expected habitat, at appropriate times (diurnal, seasonal, annual), throughout its historic range have failed to record an individual" (IUCN, 2001).

Of the 223 reptilian species classed as threatened, around half (47%) were assigned to the Vulnerable category; another 41% and 12% were assessed as Endangered and Critically Endangered, respectively. Threat estimates for terrestrial species mirrored that recorded for all reptiles (19% threatened), because the vast majority of reptiles inhabit terrestrial systems (N = 1,473; Table 1). However, for reptiles associated with marine and freshwater environments, 30% were estimated to be threatened (N = 94; Table 1). Note that 68 species were dependent on both terrestrial and non-terrestrial environments.

Of the 124 species reassessed during this project, 72 species did not change from the previously assigned category. Overall, 46 category changes were documented, only three of which were genuine changes showing an increase in extinction risk. All other changes (N = 43) were non-genuine changes. Six species had previously been listed on the IUCN Red List as Not Evaluated, but have now been assigned categories.

3.2 Global species richness and distribution of threatened and Data Deficient reptiles

Overall species richness in our sample was highest in tropical regions, specifically in Central America and parts of northern South America (especially Brazil), tropical West Africa, parts of Southeast Africa, Sri Lanka and Southern India and throughout Southeast Asia, from Eastern India to Indonesia and the Philippines (Fig. 1).

The tropics also harboured the highest proportions of threatened and Data Deficient species in the sample. Data deficiency was highest in the Indomalayan realm (33%), followed by the Neotropics (20%) and Afrotropics (18%; Table 1). A high percentage of Data Deficient species will give rise to wide margins of uncertainty on any estimates of the percentage of threatened species (see upper and lower margins in Table 1). Oceania had the highest proportion of threatened species (43%; Table 1), although this was based on very low species richness in our sample (N = 7), while 25% and 20% of species were estimated as threatened in the Afrotropical and Neotropical realms, respectively (Table 1). The lowest level of extinction risk was recorded in the Palaearctic, where 12% of species were estimated as threatened (Table 1).

Localised centres of threatened species richness were particularly apparent in the Caribbean (Hispaniola), Florida and the Florida panhandle, the Ecuadorian Andes, Madagascar, the northeastern Indian subcontinent, Central Asia, Eastern China and oceanic islands such as New Caledonia (Fig. 2A). Prevalence of Near Threatened species was particularly pronounced across Europe, central North America, Central and West Africa, Central China and the South Island of New Zealand (Fig. 2B). Data deficiency was particularly pronounced in tropical regions, specifically in parts of the Indomalayan realm (e.g., throughout India, Borneo and the Philippines) and Central Africa (Fig. 2C).

Some apparently low-diversity areas (for species richness, as well as threatened species richness) are likely explained by the lack of research in particularly inaccessible areas (e.g., the Congo basin; Fig. 2C) and isolated island groups. It is likely that both relative species richness and data deficiency is higher in these areas than is currently apparent. Furthermore, in some localised areas, the fact that all our analysis was based on a random sample may have led to a slight underestimate of species richness, threatened species richness or Data Deficient species richness. Additional maps of species richness are available in the online supplementary material (S4).

3.3 Global distribution of threat processes

Over 80% of all threatened species in our sample were affected by more than one threat process. Agriculture and biological resource use (predominantly logging and harvesting) present the most common threats to terrestrial reptiles (74% and 64% of threatened species affected, respectively). Urban development (34%), natural system modification (by use of fire, damming, etc., 25%) and invasive or problematic native species (22%) also played a role in threat to terrestrial species.

Biological resource use was also the most significant threat to freshwater and marine reptiles (87% of threatened species), with most of this threat stemming from targeted harvesting of species. This reflects the large percentage of turtles in the threatened freshwater and marine sample and their role in human trade activities. Agriculture and aquaculture, urban development and pollution (all affecting 43% of threatened species) were also significant threats to non-terrestrial reptiles.

Species richness of terrestrial and freshwater species affected by habitat loss was particularly high in tropical regions, especially in the Indomalayan realm (mainland southeast Asia, Sri Lanka, Indonesia, the Philippines and Borneo), but also in Central America (specifically Panama and Costa Rica) and northern South America (especially Brazil) (Fig. 3A). Harvesting was highlighted as a major threat in the Indomalayan realm, specifically in southeastern Asia, Java and eastern parts of the Indian sub-continent (Fig. 3B). Both of these patterns were largely reflecting underlying species distribution and richness patterns shown in Figure 1. Controlling for species richness per grid cell, habitat loss remained an important factor in parts of Sri Lanka and north-western South America, and additionally in Madagascar, with high risk also in some areas of lower reptilian species richness, namely across central USA, the Caribbean, southwestern Europe (particularly Spain), localised areas of North and East Africa, China, northeastern Australia and the South Island of New Zealand (Fig. 3C). Similarly, the picture of risk through harvesting changed to similar areas of lower richness by controlling for species richness per grid cell, with large parts of Europe and Central Asia particularly highlighted (Fig. 3D). In addition to habitat loss and harvesting, invasive species appear to increase extinction risk on islands, but relatively low frequencies of this threat in our sample mask any pattern at the global scale. However, invasive species pose the main threat in New Caledonia, Oceania, New Zealand, southern Australia and on Caribbean islands.

3.4 Taxonomic differences in extinction risk

The percentage of threatened species varied greatly among higher-level taxa, driven by the relatively higher levels of threat to species associated with freshwater and marine habitats compared with terrestrial ones (Table 1), as well as taxa-specific patterns of range size. Three of the four crocodilian species and 52% of freshwater turtles were estimated to be threatened (N = 37, margins: 46-57%). As a whole, Testudines (N = 46; comprising 37 freshwater species, one marine species and eight terrestrial species) were equally spread among Red List categories, with 51% of species estimated as threatened and another 22% assessed as Near Threatened (Table 1). In contrast, only 21% of lizards, 12% of snakes and 7% of worm lizards were threatened. The lower percentages in threatened species of these groups were paralleled by a lower percentage of species in the Near Threatened category for all three groups (lizards: 7%; snakes: 5%; worm lizards: 14%), compared with Testudines. Proportions of threatened worm lizards were affected by high levels of data deficiency in this group (50% versus 11% in the Testudines, 19% in lizards and 24% in snakes; Table 1). Similarly, our sample contained large numbers of Data Deficient species in snake families that are exclusively, or largely, fossorial or semi-fossorial, such as Typhlopidae [24 out of 49 species (49%) were Data Deficient], Leptotyphlopidae [4 out of 10 (40%)] and Uropeltidae [5 out of 13 (38%)]. Overall, of the exclusively or primarily fossorial families, 47% of species were classed as Data Deficient. As a result, the estimated percentage of threatened fossorial species is relatively low at 11%, but this is associated with a wide margin of uncertainty (range: 6–57%).

Criterion B was applied to 72% of species assessed as threatened, with another 12% of species being listed under criterion D2. As such, the majority of threatened listings were based on criteria of restricted range rather than population data (only 12% of species, mainly turtles and crocodiles, were listed under criterion A). As a result, range size differences between taxa may at least in part explain differences in perceived extinction risk. Range sizes were significantly larger for snakes compared to lizards (for terrestrial species only: Kruskal-Wallis $\chi^2 = 44.8$, d.f. = 1, $p<0.001$). Median range size was 24,510 km^2 for lizards and 110,175 km^2 for snakes (additional information is available in section S5 of the online supplementary material).

To establish whether a particular taxonomic family was at greater risk of extinction than expected by chance ($p<0.025$) required a minimum of three non-Data

Deficient species in our sample from that family, given a background proportion of 223 threatened species from 1,182 species assessed in non-Data Deficient categories. As a result, 18 families were excluded from the analysis (Table 2). Each family required a minimum number of 18 species in our sample to establish whether a family was less threatened than expected by chance ($p<0.025$). Threat was not evenly distributed across families ($\chi^2 = 141.73$, d.f. = 44, $p<0.001$), with 34 of the 45 families more threatened than expected by chance and only one (Colubridae) less threatened than expected by chance (Table 2). Of the nine families which showed non-significant differences between observed and expected proportions of threatened species, six were snakes, two were lizards and one was turtles (Table 2).

Overall, the most threatened families were the Geoemydidae (turtles, 88% threatened, $N = 8$), Crocodylidae (crocodiles, 75%, $N = 4$), Pygopodidae (lizards, 75%, $N = 4$), Xantusiidae (lizards, 75%, $N = 4$), Chelidae (turtles, 50%, $N = 11$) and Iguanidae (lizards, 50%, $N = 4$) (Table 2).

4. Discussion

4.1 Extinction risk of the world's reptiles

This analysis starts to close the knowledge gap between the extinction risk of reptiles and other better-studied vertebrate groups. By establishing a shortcut using a representative sample of 1,500 species, we gain for the first time an overview of the global distribution of reptilian diversity and threat, consequently highlighting important areas for conservation attention and gaps in knowledge. Our results support recent reports of high levels of threat in freshwater habitats (e.g., freshwater crabs; Cumberlidge et al., 2009). In particular, freshwater turtles were highly threatened (46–57%), thus mirroring the alarming trends reported elsewhere (Buhlmann et al., 2009).

Some authors have argued that reptiles are undergoing similar declines to those experienced by amphibians, in terms of taxonomic breadth, geographic scope and severity (Gibbons et al., 2000). On a global scale, our assessment shows that threat levels are more severe in amphibians (42% of amphibians are threatened, assuming Data Deficient species are threatened in the same proportion as non-Data Deficient species) relative to reptiles (20%). Overall, threat levels in reptiles are slightly lower than those observed in other taxa such as mammals and freshwater fish (both 25% threatened; Collen, B., unpublished data; Hoffmann et al., 2010), but higher than in birds (13%; IUCN, 2011a). Estimates of 5% for Near Threatened

species were similar to those observed in other vertebrate species groups, such as mammals, amphibians (6% each) and freshwater fishes (4%).

Recently reported local declines in snake and lizard populations (Cagle, 2008; Reading et al., 2010; Sinervo et al., 2010) suggest localised elevated extinction risks for both taxa. While we estimate that about one in five lizard species is threatened with extinction, only 12% of snakes were estimated to be threatened with extinction. One barrier to listing, which could be partly responsible for the discrepancy between our analysis and those of snake population trends, is that in the majority of cases there are sufficient data on species distributions only, rather than population trends, on a global scale. Therefore the majority of reptilian species were listed under criteria B and D2 (restricted range). The differences in extinction risk between snakes and lizards may therefore be partly explained by the fact that snakes in our sample (and in previous studies, e.g., Anderson and Marcus, 1992) had larger ranges than lizards. Local population declines such as those reported by Sinervo et al. (2010) are evaluated with finer scale population data than those used to evaluate extinction risk, so could serve as a warning sign of what is to come. In order to understand more fully what is happening to the world's snakes, it is vital that we obtain better global population data for this species group. Based on range size estimation alone, we may be missing ongoing declines which are occurring at sub-threshold levels and thus underestimating extinction risk to this particular species group. Furthermore, snakes are morphologically more conservative and harder to sample (fewer specimens are generally available compared to lizards) which, compared to lizards, makes it harder to detect cryptic species. Thus, larger ranges for some snake species may be masking the ranges of two or more cryptic species.

4.2 Data deficiency: addressing the knowledge gap

High proportions of data deficiency can significantly hinder our understanding of threat, yet such uncertainty is apparent in many species groups that have been assessed to date. Levels of data deficiency in reptiles (21%) were lower than those reported for amphibians (25%; IUCN, 2011a), dragonflies and damselflies (35%; Clausnitzer et al., 2009) and freshwater crabs (49%; Cumberlidge et al., 2009), but still exceeded those of the more charismatic or conspicuous birds and mammals (less than 1% and 15% respectively; BirdLife International, 2008b; Schipper et al., 2008). Patterns of regional or taxonomical data deficiency could be used to prompt research

programmes on specific local faunas or taxonomical groups. For example, data deficiency in reptiles was highest in tropical regions and in exclusively fossorial or semi-fossorial reptiles such as the Amphisbaenia. Similar patterns have been observed in amphibians, where approximately two-thirds of caecilians were classified as Data Deficient (Gower et al., 2005), despite estimates that fossorial species potentially comprise around 20% of the world's herpetofauna (Measey, 2006). It is clear that research attention should focus specifically on fossorial and other elusive taxa (e.g., arboreal species) in order to reduce rates of data deficiency during the course of future re-assessments of the sample.

4.3 Conservation prioritisation: lessons from the world's reptiles

Conservation priorities often focus on regions of high biodiversity value and/or high threat to effectively target conservation funds (Brooks et al., 2006). The assessment of biodiversity value often relies on the distribution patterns of certain indicator taxa (e.g., birds), and the effectiveness of the resulting prioritisation mechanism greatly depends on the degree to which such distribution patterns are congruent with those of other taxa. However, cross-taxon congruence varies with given metrics of biodiversity (Grenyer et al., 2006). While reptilian species richness broadly mirrored species richness patterns observed in mammals, amphibians and birds (BirdLife International, 2008a; Schipper et al., 2008; Stuart et al., 2004), additional areas rich in reptiles (e.g., around the Gulf of Guinea and southern Africa) or threatened reptiles (e.g., islands such as Hispaniola, Sri Lanka, New Caledonia) were highlighted in our assessment and may be overlooked if conservation priorities are set based on patterns in a small number of non-reptilian taxa alone. This has also recently been demonstrated for Australian lizards (Powney et al., 2010). Thus far, both amphibians and reptiles have been greatly overlooked in reserve selection strategies based on coarse-scale biodiversity surrogate measures (Araújo et al., 2001). Our results provide the opportunity for a more representative view of biodiversity to be compiled in order to benefit multiple taxa.

Assessing the global distribution of threat processes, both current and projected, has the potential to provide another powerful tool for conservation prioritization. While for some taxa, the distribution of predominant threats significantly overlaps areas of high species richness (e.g., amphibians, Hof et al., 2011), other studies have shown incongruence between threat distribution and

endemic or threatened species richness (e.g., Grenyer et al., 2006; Lee and Jetz, 2008; Orme et al., 2005); however, the latter has traditionally been favoured as a selection tool for conservation priority areas. Similarly, distributions of different threat types may not always spatially overlap (Hof et al., 2011), so that effective mitigation strategies have to be developed in a spatially explicit context in order to reduce extinction risk of species. Reptiles in general are particularly sensitive to habitat degradation because of their comparatively low dispersal ability, morphological specialisation on substrate type, relatively small home ranges and thermoregulatory constraints (Kearney et al., 2009). Clearly, the distribution and severity of threat processes, such as habitat loss from agricultural conversion, logging and over-exploitation, will shape the future fortune of reptiles. Identifying centres of threat, and tackling the origins and effects of anthropogenic threats in these regions through targeted projects (particularly in areas affected by multiple threat processes such as Southeast Asia) will allow more proactive action to be taken to secure the future of reptiles. At the moment the spatial resolution of our species-specific maps of threat processes is still somewhat coarse and allows only the depiction of broad patterns in threat distribution, but future developments and refinements of the method are likely to provide a powerful tool with which to focus threat-specific mitigation projects.

4.4 Reptile conservation: the next steps

This work provides a first step in assessing the global extinction risk of reptiles by employing a short-cut method based on a representative sample of 1,500 species. While this assessment feeds into broader scale assessments of biodiversity as a whole, as part of the Sampled Red List Index project (Baillie et al., 2008), it is also important to feed this information into similar regional assessments, since concrete policy decisions are generally being taken at sub-global levels. Specifically, it is important that the data presented here is used to assess how existing and planned protected areas are benefitting the world's reptiles. This will allow us to identify species which at present fall outside protected areas and are most in need of conservation actions, and address the fact that the world's herpetofauna is still often overlooked when conservation decisions are taken. The Global Reptile Assessment (GRA) is currently carrying out assessments via regional workshops, which bring together species experts to discuss extinction risk and conservation priorities. For example, the recent assessment of Madagascan snakes and lizards has helped in

evaluating the effectiveness of protected areas for reptiles, with new conservation areas being designated across the island aiming to provide protection to some of the most threatened species (IUCN, 2011b).

While the extensive expert network established during this project is undoubtedly going to feed into global and regional assessment projects, regional data gaps are apparent. It is vital that these are addressed in order to complete our picture of the distribution and extinction risk patterns of reptiles, so that conservation actions can be targeted at regions and areas most in need. Specifically, surveys are needed for key areas (e.g., areas rich in Data Deficient reptiles) and species (e.g., possibly extinct and Data Deficient species; establishing snake population time series to complement distribution data) in order to fill knowledge gaps and to build regional survey capacity via collaborations and targeted capacity building projects.

While we have established a snapshot of the current status of reptiles worldwide, it is now vital to establish trends in this status in order to gauge the rate of change in reptilian extinction risk over time. The next step is to establish a baseline for reptilian extinction risk against which we can compare current status as well as future re-assessments of the sample. This information is vital in order to assess our progress toward global biodiversity targets, such as the Aichi targets and the Millennium Development Goals, and fuel efforts to address the conservation needs of reptiles.

Acknowledgements

MB and MR were funded by a grant from the Esmée Fairbairn Foundation, BC by the Rufford Foundation. North American and Mexican species assessments were funded by the Regina Bauer Frankenberg Foundation for Animal Welfare. Species assessments under the Global Reptile Assessment (GRA) initiative are supported by: Moore Family Foundation, Gordon and Betty Moore Foundation, Conservation International, Critical Ecosystem Partnership Fund (CEPF), and European Commission. Additional acknowledgements are included in the online supplementary material.

The assessment workshop for Mexican reptiles was kindly hosted by Ricardo Ayala and the station personnel of the Estación de Biología Chamela, Instituto de Biología, Universidad Nacional Autonoma de Mexico. Workshop and logistical organization of the Philippines assessments was provided by the Conservation

International Philippines Office, in particular Ruth Grace Rosell-Ambal, Melizar V. Duya and Oliver Coroza. Workshop and logistical organization for the European Reptile and Amphibian Assessments was provided by Doğa Derneği, in particular Özge Balkiz and Özgür Koç. Workshop and logistical organization for assessments of sea snakes and homalopsids was provided by the International Sea Turtle Symposium and Dr. Colin Limpus (Australian Government Environmental Protection Agency). Special thanks to Jenny Chapman (EPA) and Chloe Schauble (ISTS). Thank you also to Dr. Gordon Guymer (Chief Botanist – Director of Herbarium) for accommodating us at the Herbarium in the Brisbane Botanical Gardens, and Mark Read and Kirsten Dobbs (Great Barrier Reef Marine Parks Association) and Dave Pollard and Brad Warren (OceanWatch Australia) for institutional support. Mohamed Bin Zayed Species Conservation Fund, Conservation International Madagascar and the Darwin Initiative contributed to funding the costs of the Madagascar reptile workshop.

We would also particularly like to thank all our assessors and the following people who helped with the compilation and finalization of SRLI Red List assessments and distribution maps: Jennifer Sears, Gary Powney, Paul Lintott, Sarah Lewis, Penny Wilson, Maiko Lutz, Felix Whitton, Ranmali de Silva and Harriet Milligan. For facilitating working groups at GRA and other workshops: Melanie Bilz, Thomas Brooks, Oliver Coroza, Naamal De Silva, Melizar V. Duya, Michael Jensen, Jason Van de Merwe, Kate Hodges, Matthew Foster, Penny Langhammer, Seema Mundoli, Ana Nieto, Lily Paniagua, Ruth Grace Rosell-Ambal, Jan Schipper and Sarah Wyatt.

Shai Meiri, Lital Dabool, Anat Feldman, Yuval Itescu, Amy Kadison, Erez Maze, Maria Novosolov, Lian Pin Koh and other anonymous reviewers commented on and helped to greatly improve an earlier version of this manuscript.

References

Adalsteinsson, S.A., Branch, W.R., Trape, S., Vitt, L.J., Hedges, S.B., 2009. Molecular phylogeny, classification, and biogeography of snakes of the Family Leptotyphlopidae (Reptilia, Squamata). Zootaxa 2244, 1-50.

Anderson, S., 1984. Aerography of North American fishes, amphibians, and reptiles. American Museum Novitates 2802, 1-6.

Anderson, S., Marcus, L., F., 1992. Aerography of Australian Tetrapods. Australian Journal of Zoology 40, 627-651.

1 Araújo, M.B., Humphries, C.J., Densham, P.J., Lampinen, R., Hagemeijer, W.J.M.,
2 Mitchell-Jones, A.J., Gasc, J.P., 2001. Would environmental diversity be a good
3 surrogate for species diversity? Ecography 24, 103-110.
4 Baillie, J.E.M., Collen, B., Amin, R., Akcakaya, H.R., Butchart, S.H.M., Brummitt,
5 N., Meagher, T.R., Ram, M., Hilton-Taylor, C., Mace, G.M., 2008. Towards
6 monitoring global biodiversity. Conservation Letters 1, 18-26.
7 Bates, M.F., Branch, W.R., Bauer, A.M., Burger, M., Marais, J., Alexander, G.J., de
8 Villiers, M.S. eds., in prep. Atlas and Red List of the Reptiles of South Africa,
9 Lesotho and Swaziland. South African National Biodiversity Institute, Pretoria, South
10 Africa.
11 Bielby, J., Cunningham, A.A., Purvis, A., 2006. Taxonomic selectivity in amphibians:
12 ignorance, geography or biology? Animal Conservation 9, 135-143.
13 BirdLife International, 2008a. State of the world's birds: indicators for our changing
14 world. BirdLife International, Cambridge, UK.
15 BirdLife International, 2008b. State of the world's birds: indicators for our changing
16 world. BirdLife International, Cambridge, UK.
17 Brooks, T.M., Mittermeier, R.A., da Fonseca, G.A.B., Gerlach, J., Hoffmann, M.,
18 Lamoreux, J.F., Mittermeier, C.G., Pilgrim, J.D., Rodrigues, A.S.L., 2006. Global
19 biodiversity conservation priorities. Science 313, 58-61.
20 Buhlmann, K.A., Akre, T.S.B., Iverson, J.B., Karapatakis, D., Mittermeier, R.A.,
21 Georges, A., Rhodin, A.G.J., van Dijk, P.P., Gibbons, J.W., 2009. A global analysis
22 of tortoise and freshwater turtle distributions with identification of regional priority
23 conservation areas. Chelonian Conservation and Biology 8, 116-149.
24 Butchart, S.H.M., Bird, J.P., 2010. Data Deficient birds on the IUCN Red List: what
25 don't we know and why does it matter? Biological Conservation 143, 239-247.
26 Cagle, N.L., 2008. Snake species distributions and temperate grasslands: a case study
27 from the American tallgrass prairie. Biological Conservation 141: 744-755.
28 Cardillo, M., Meijaard, E., 2011. Are comparative studies of extinction risk useful for
29 conservation? Trends in Ecology & Evolution 27, 167-171.
30 Clausnitzer, V., Kalkman, V.J., Ram, M., Collen, B., Baillie, J.E.M., Bedjanic, M.,
31 Darwall, W.R.T., Dijkstra, K.-D.B., Dow, R., Hawking, J., Karube, H., Malikova, E.,
32 Paulson, D., Schütte, K., Suhling, F., Villanueva, R., von Ellenrieder, N., Wilson, K.,
33 2009. Odonata enter the biodiversity crisis debate: the first global assessment of an
34 insect group. Biological Conservation 142, 1864-1869.

Collen, B., Turvey, S.T., Waterman, C., Meredith, H.M.R., Kuhn, T.S., Baillie, J.E.M., Isaac, N.J.B., 2011. Investing in evolutionary history: implementing a phylogenetic approach for mammal conservation. Philosophical Transactions of the Royal Society of London B 366, 2611-2622.

Collen, B., Kamran, S., Böhm, M., Baillie, J.E.M., in prep. Spatial representation of the sampled approach to Red Listing.

Cox, N.A., Temple, H.J., 2009. European Red List of Reptiles. Office for Official Publications of the European Communities, Luxembourg

Cumberlidge, N., Ng, P.K.L., Yeo, D.C.J., Magalhães, C., Campos, M.R., Alvarez, F., Naruse, T., Daniels, S.R., Esser, L.J., Attipoe, F.Y.K., Clotilde-Ba, F.-L., Darwall, W., McIvor, A., Baillie, J.E.M., Collen, B., Ram, M., 2009. Freshwater crabs and the biodiversity crisis: Importance, threats, status, and conservation challenges. Biological Conservation 142, 1665-1673.

Gibbons, J.W., Scott, D.E., Ryan, T.J., Buhlmann, T.D., Metts, B.S., Greene, J.L., Mills, T., Leiden, Y., Poppy, S., Winne, C.T., 2000. The global decline of reptiles, déjà vu amphibians. BioScience 50, 653-666.

Gower, D.J., Stuart, S.N., Bhatta, G., Cox, N., Gerlach, J., Loader, S.P., Long, J., Lynch, J.D., Measey, G.J., Nussbaum, R.A., Oommen, O.V., Manamendra-Arachchi, K., Ravichandran, M.S., Wilkinson, M., Young, B.E., 2005. Caecilians and the 2004 Global Amphibian Assessment. Conservation Biology 19, 54-55.

Grenyer, R., Orme, C.D.L., Jackson, S.F., Thomas, G.H., Davies, R.G., Davies, T.J., Jones, K.E., Olson, V.A., Ridgely, R.S., Rasmussen, P.C., Ding, T.-S., Bennett, P.M., Blackburn, T.M., Gaston, K.J., Gittleman, J.L., Owens, I.P.F., 2006. Global distribution and conservation of rare and threatened vertebrates. Nature 444, 93-96.

Han, D., Zhou, K., Bauer, A.M., 2004. Phylogenetic relationships among gekkotan lizards inferred from *Cmos* nuclear DNA sequences and a new classification of the Gekkota. Biological Journal of the Linnean Society 83, 353–368.

Hedges, S.B., Poling, L.L., 1999. A molecular phylogeny of reptiles. Science 283, 998-1001.

Hof, C., Araújo, M.B., Jetz, W., Rahbek, C., 2011. Additive threats from pathogens, climate and land-use change for global amphibian diversity. Nature 480, 516-519.

Hoffmann, M., Hilton-Taylor, C., Angulo, A., Böhm, M., Brooks, T.M., Butchart, S.H.M., Carpenter, K.E., Chanson, J., Collen, B., Cox, N.A., Darwall, W.R.T., Dulvy, N.K., Harrison, L.R., Katariya, V., Pollock, C.M., Quader, S., Richman, N.I.,

1 Rodrigues, A.S.L., Tognelli, M.F., Vié, J.-C., et al., 2010. The Impact and Shortfall of
2 Conservation on the Status of the World's Vertebrates. Science 330, 1503-1509.
3 IUCN, 2001. IUCN Red List Categories and Criteria: Version 3.1. IUCN, Gland,
4 Switzerland.
5 IUCN, 2011a. The IUCN Red List of Threatened Species 2011.2.
6 IUCN, 2011b. News release (10/11/2011): Another leap towards the Barometer of
7 Life. IUCN, Gland, Switzerland, http://www.iucnredlist.org/news/another-leap-
8 towards-the-barometer-of-life.
9 Kearney, M., Shine, R., Porter, W.P., 2009. The potential for behavioral
10 thermoregulation to buffer "cold-blooded" animals against climate warming.
11 Proceedings of the National Academy of Sciences USA 106, 3835-3840.
12 Lee, T.M., Jetz, W., 2008. Future battlegrounds for conservation under global change.
13 Proceedings of the Royal Society B-Biological Sciences 275, 1261-1270.
14 Mace, G.M., Collar, N.J., Gaston, K.J., Hilton-Taylor, C., Akcakaya, H.R., Leader-
15 Williams, N., Milner-Gulland, E.J., Stuart, S.N., 2008. Quantification of extinction
16 risk: IUCN's system for classifying threatened species. Conservation Biology 22,
17 1424-1442.
18 Measey, G.J., 2006. Surveying biodiversity of soil herpetofauna: towards a standard
19 quantitative methodology. European Journal of Soil Biology 42, S103-S110.
20 Nagy, Z.T., Sonet, G., Glaw, F., Vences, M., 2012. First large-scale DNA barcoding
21 assessment of reptiles in the biodiversity hotspot of Madagascar, based on newly
22 designed COI primers. PLos One 7, e34506.
23 Oliver, P.M., Adams, M., Lee, M.S.Y., Hutchinson, M.N., Doughty, P., 2009. Cryptic
24 diversity in vertebrates: molecular data double estimates of species diversity in a
25 radiation of Australian lizards (*Diplodactylus*, Gekkota) Proceedings of the Royal
26 Society B-Biological Sciences 276, 2001-2007.
27 Orme, C.D.L., Davies, R.G., Burgess, M., Eigenbrod, F., Pickup, N., Olson, V.A.,
28 Webster, A.J., Ding, T.S., Rasmussen, P.C., Ridgely, R.S., Stattersfield, A.J., Bennett,
29 P.M., Blackburn, T.M., Gaston, K.J., Owens, I.P.F., 2005. Global hotspots of species
30 richness are not congruent with endemism or threat. Nature 436, 1016-1019.
31 Powney, G.D., Grenyer, R., Orme, C.D.L., Owens, I.P.F., Meiri, S., 2010. Hot, dry
32 and different: Australian lizard richness is unlike that of mammals, amphibians and
33 birds. Global Ecology and Biogeography 19, 386-396.

R Development Core Team, 2007. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria.

Raxworthy, C.J., Pearson, R.G., Zimkus, B.M., Reddy, S., Deo, A.J., Nussbaum, R.A., Ingram, C.M., 2008. Continental speciation in the tropics: contrasting biogeographic patterns of divergence in the *Uroplatus* leaf-tailed gecko radiation of Madagascar. Journal of Zoology 275, 423-440.

Read, J.L., 1998. Are geckos useful bioindicators of air pollution? . Oecologia 114, 180-187.

Reading, C.J., Luiselli, L.M., Akani, G.C., Bonnet, X., Amori, G., Ballouard, J.M., Filippi, E., Naulleau, G., Pearson D., Rugiero, L., 2010. Are snake populations in widespread decline? Biology Letters 6, 777-780.

Reisz, R.R., Modesto, S.P., Scott, D.M., 2011. A new Early Permian reptile and its significance in early diapsid evolution. Proceedings of the Royal Society B-Biological Sciences, doi:10.1098/rspb.2011.0439.

Salafsky, N., Salzer, D., Stattersfield, A.J., Hilton-Taylor, C., Neugarten, R., Butchart, S.H.M., Collen, B., Cox, N., Master, L.L., O'Connor, S., Wilkie, D., 2008. A standard lexicon for biodiversity conservation: unified classifications of threats and actions. Conservation Biology 22, 897-911.

Schipper, J., Chanson, J.S., Chiozza, F., Cox, N.A., Hoffmann, M., Katariya, V., Lamoreux, J., Rodrigues, A.S.L., Stuart, S.N., Temple, H.J., Baillie, J., Boitani, L., Lacher, T.E., Mittermeier, R.A., Smith, A.T., Absolon, D., Aguiar, J.M., Amori, G., Bakkour, N., Baldi, R., et al., 2008. The Status of the World's Land and Marine Mammals: Diversity, Threat, and Knowledge. Science 322, 225-230.

Sinervo, B., Méndez-de-la-Cruz, F., Miles, D.B., Heulin, B., Bastiaans, E., Villagrán-Santa Cruz, M., Lara-Resendiz, R., Martínez-Méndez, N., Calderón-Espinosa, M.L., Meza-Lázaro, R.N., Gadsden, H., Avila, L.J., Morando, M., De la Riva, I.J., Sepulveda, P.V., Duarte Rocha, C.F., Ibargüengoytía, N., Aguilar Puntriano, C., Massot, M., Lepetz, V., et al., 2010. Erosion of lizard diversity by climate change and altered thermal niches. Science 328, 894-899.

Stuart, S.N., Chanson, J.S., Cox, N.A., Young, B.E., Rodrigues, A.S., Fischman, D.L., Waller, R.W., 2004. Status and trends of amphibian declines and extinctions worldwide. Science 306, 1783-1786.

Todd, B.D., Willson, J.D., Gibbon, J.W., 2010. The global status of reptiles and causes of their decline, In Ecotoxicology of amphibians and reptiles, 2nd edition. eds D.W. Sparling, G. Linder, C.A. Bishop, S. Krest. CRC Press, Boca Raton, USA.

Uetz, P., 2010. The original descriptions of reptiles. Zootaxa 2334, 59-68.

van Tuinen, M., Hadly, E.A., 2004. Error in estimation of rate and time inferred from the early amniote fossil record and avian molecular clocks. Journal of Molecular Evolution 59, 267-276.

Vidal, N., Hedges, S.B., 2009. The molecular evolutionary tree of lizards, snakes, and amphisbaenians. Comptes Rendus Biologies 332, 129-139.

Zaher, H., Grazziotin, F.G., Cadle, J.E., Murphy, R.W., de Moura-Leite, J.C., Bonatto, S.L., 2009. Molecular phylogeny of advanced snakes (Serpentes, Caenophidia) with an emphasis on South American Xenodontines: a revised classification and descriptions of new taxa. Papéis Avulsos de Zoologia 49, 115-153.

Figure legends

Figure 1. Global species richness distribution of the sampled reptile assessment ($N_{terr/fw}$ = 1,485; N_{marine} = 22). Terr/fw – terrestrial and freshwater species.

Figure 2. Distribution of threatened (CR, EN, VU), Near Threatened (NT) and Data Deficient (DD) species in the sample (terrestrial and freshwater only), expressed as the proportion of all species present per grid cell: A) proportion of species classed as threatened, adjusted to account for DD species as described in section 2.3; B) proportion of species classed as Near Threatened, adjusted to account for DD species as described in section 2.3; and C) proportion of species classed as Data Deficient per grid cell.

Figure 3. Global distribution of species affected by the two major threats to terrestrial and freshwater reptiles: A) number of species affected by habitat loss from agriculture and logging and B) number of species affected by harvesting. Controlling for species richness per grid cell, we expressed the number of species in elevated threat categories (CR, EN, VU, NT) affected by the threat in question as the proportion of the total species richness (all categories) per grid cell for C) habitat loss from agriculture and logging and D) harvesting.

Tables

Table 1. Extinction risk in a subsample of 1,500 reptiles by order, biogeographic realm and habitat system. The number of species falling into each IUCN Category are listed, from which % threatened has been calculated as described in section 2.3

								No. of species		% threatened		
Taxon	**DD**	**LC**	**NT**	**VU**	**EN**	**CR**	***N***	**Described**	**% sampled**	**Threatened %**	**Lower**	**Upper**
Reptiles	318	881	78	105	92	26	1500	9413	15.9	18.9	14.9	36.1
Amphisbaenia	14	11	2	0	1	0	28	181	15.5	7.1	3.6	53.6
Crocodylia	0	1	0	2	0	1	4	24	16.7	75	75	75
Sauria	164	506	48	72	63	14	867	5,537	15.7	21.2	17.2	36.1
Serpentes	135	352	19	24	20	5	555	3,346	16.6	11.7	8.8	33.2
Testudines	5	11	9	7	8	6	46	323	14.2	51.2	45.7	56.5
Realm												
Afrotropical	53	161	15	33	22	5	289			25.4	20.8	39.1
Australasian	32	149	9	10	14	5	219			15.5	13.2	27.9
Indomalayan	105	167	13	15	10	5	315			14.3	9.5	42.9
Nearctic	2	72	7	7	3	3	94			14.1	13.8	16.0
Neotropical	107	309	27	38	35	11	527			20.0	15.9	36.2
Oceanian	0	4	0	0	2	1	7			42.9	42.9	42.9
Palaearctic	25	105	8	6	8	2	154			12.4	10.4	26.6
Habitat system												
Terrestrial	313	861	78	105	91	25	1473			19.1	15.0	36.3
Freshwater & marine	16	44	11	9	8	6	94			29.5	24.5	41.5
Subsurface	50	46	5	1	5	0	107			10.5	5.6	57.0

DD – Data Deficient; LC – Least Concern; NT – Near Threatened; VU – Vulnerable; EN – Endangered; CR – Critically Endangered. Percentage threatened: assumes DD species are threatened in the same proportion as non-DD species; Lower margin: no DD species threatened; Upper margin: all DD species threatened. Number of described species is based on Uetz (2010). Rhynchocephalia (Tuatara) was not represented in our random sample. Subsurface includes completely or primarily fossorial families: Amphisbaenidae, Anomalepidae, Dibamidae, Leptotyphlopidae, Trogonophidae, Typhlopidae, Uropeltidae, Xenopeltidae.

Table 2. Threat distribution across families included in our random sample of 1,500 species: ns, not significant; - significantly under threatened; + significantly over threatened.

Family	Proportion observed	Proportion expected	Total species (non-DD)	>Expected threat level p-value	<Expected threat level p-value	Under or over threatened
Agamidae	0.05	0.05	61	0.635	0.365	ns
Amphisbaenidae	0.07	0.01	14	<0.001	1	+
Anguidae	0.29	0.01	17	<0.001	1	+
Atractaspidae	0.00	0.00	6	0.714	0.286	ns
Boidae	0.15	0.01	13	<0.001	1	+
Calamariidae	0.18	0.01	11	<0.001	1	+
Carphodactylidae	0.17	0.00	6	<0.001	1	+
Chamaeleonidae	0.43	0.03	35	<0.001	1	+
Chelidae	0.50	0.01	10	<0.001	1	+
Colubridae	0.04	0.07	78	0.98	0.02	-
Cordylidae	0.44	0.01	9	<0.001	1	+
Crocodylidae	0.75	0.00	4	<0.001	1	+
Crotaphytidae	0.33	0.00	3	<0.001	1	+
Diplodactylidae	0.23	0.01	13	<0.001	1	+
Dipsadidae	0.10	0.08	98	0.147	0.853	ns
Elapidae	0.15	0.05	55	<0.001	1	+
Emydidae	0.33	0.00	6	<0.001	1	+
Gekkonidae	0.12	0.08	91	0.01	0.999	+
Geoemydidae	0.88	0.01	8	<0.001	1	+
Gerrhosauridae	0.17	0.00	6	<0.001	1	+
Gymnophthalmidae	0.39	0.03	31	<0.001	1	+
Homalopsidae	0.17	0.00	6	<0.001	1	+
Iguanidae	0.50	0.00	4	<0.001	1	+
Lacertidae	0.16	0.03	37	<0.001	1	+
Lamprophiidae	0.27	0.03	30	<0.001	1	+
Leptotyphlopidae	0.00	0.00	6	0.72	0.28	ns
Natricidae	0.04	0.02	26	0.049	0.951	+
Pelomedusidae	0.00	0.00	4	0.566	0.434	ns
Phrynosomatidae	0.17	0.03	30	<0.001	1	+
Phyllodactylidae	0.08	0.01	13	<0.001	1	+
Polychrotidae	0.31	0.05	61	<0.001	1	+
Psammophiidae	0.00	0.00	4	0.596	0.404	ns
Pseudoxenodontidae	0.00	0.00	3	0.468	0.532	ns
Pygopodidae	0.75	0.00	4	<0.001	1	+
Scincidae	0.22	0.14	167	<0.001	1	+
Sphaerodactylidae	0.22	0.03	32	<0.001	1	+
Teiidae	0.22	0.01	18	<0.001	1	+
Testudinidae	0.43	0.00	7	<0.001	1	+
Trionychidae	0.33	0.00	3	<0.001	1	+
Tropiduridae	0.13	0.04	45	<0.001	1	+
Typhlopidae	0.20	0.02	25	<0.001	1	+
Uropeltidae	0.00	0.00	8	0.832	0.168	ns
Varanidae	0.00	0.01	10	0.875	0.125	ns
Viperidae	0.19	0.04	42	<0.001	1	+
Xantusiidae	0.75	0.00	4	<0.001	1	+